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EQUIPMENT OF THE K-12 12-CHANNEL SYSTEM

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In this paper are described the equipment for the 12-channel system for communication over symmetric (nonloaded) cable lines, the principal electric characteristics of this equipment, block diagrams of the terminal and intermediate stations, diagrams of individual units, and also the makeup and the construction of the equipment used in these stations.

Along with aerial lines, cable communication lines have received widespread application in modern interurban telephone and telegraph communications. Cable lines, particularly those buried underground, have substantial advantages over aerial lines and provide more reliable communications.

For a long time only symmetric loaded cables with paper-card insulation were the only type used in interurban communication installations. The loading reduced the attenuation of the cable pairs, but at the same time restricted the useful frequency band and reduced the speed of propagation of the alternating current of the signal over the line. This made it possible to employ only tonal communication channels and to transmit over relatively short distances. To obtain interurban trunk lines with a large number of circuits it was necessary to employ multiconductor cables. The cost of the line structures was quite high in such communication systems.

Later, as the technique of construction of high-quality amplifiers developed, loading coils were employed with even higher limiting frequencies, and eventually loading was dispensed with for trunk lines. The latter fact, added to the improvement in the symmetrization of cable pairs for the purpose of raising the crosstalk attenuation, has permitted the use of multiple utilization of the cable pairs with the aid of high-frequency [carrier] telephony. This raised the speed of propagation of the current along the line and reduced the cost of line structure. It thus became technically possible and economically preferable to organize communication over cables at distances reaching several thousand km.

A very important step in the development of Russian long-distance communication engineering was the development and mastery of the type K-12, the 12-channel system. This system is intended for carrier communication over symmetric (nonloaded) cable lines and possesses high technical and economic indices.

Principal Technical Data on the K-12 Apparatus

The K-12 apparatus makes it possible to obtain 12 telephone channels with an effectively transmitted frequency band from 300 to 3400 cycles, over a 4-conductor cable line with paper-cord insulation and with 1.2-mm copper conductors twisted in a "star." The transmission is effected over the cable line in the frequency spectrum from 12 to 60 kc. The frequency characteristics of the per-km attenuation and of the wave impedance of this type of cable are shown in Figure 1. To insure the required high crosstalk attenuation between the pairs used for the transmission of currents in opposite directions, a 2-cable communication system is employed.

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Each channel of the K-12 system can be used also for multiple tonal telegraphy with amplitude or frequency manipulation, and also for the transmission of facsimile signals. In addition, if 2 or 3 telephone channels are interconnected, it is possible, with the aid of supplementary apparatus, to transmit music broadcasts between cities.

Individual conversion installations, similar to those used in the V-12 system, are used in the K-12 apparatus for the first stage of conversion of the telephone currents into a line frequency spectrum. At the output point of these installations the currents occupy a frequency spectrum ranging from 60 to 108 kc. By employing a single group-conversion stage with a 120-kc carrier frequency these currents are transformed into a 12 to 60 kc line frequency spectrum.

Economical electron tubes are used in the line amplifiers of the K-12 apparatus to amplify the currents in the 12-60 kc frequency range. This makes possible remote control of 2/3 of all the intermediate amplifiers, using as conductors the cables over which the high-frequency communication is carried. Thanks to this, there is no need for providing power supplies and permanent service personnel in all the amplifier stations.

In addition, the use of heavy negative feedback and partial regulation of the frequency characteristics of the gain (in the feedback chain) has led to a reduction of the effect of thermal noise and mutual nonlinear interference between the channels system in the amplifiers. This has permitted making the length of individual amplifier sections and the total maximum length of the communication line greater than all other known analogous communication systems over symmetrical cables, while still adhering to the established norms for noise. In the K-12 system the length of the amplifier section ranges from 20 to 57 km, corresponding to a maximum attenuation of a cable section of 8.5 nepers at 60 kc. The length of the relaying section may reach 2,000 km with 4 relay points.

The K-12 system, while insuring long transmission distance with high quality telephone channels, is thsu quite economical in constructional and operation activities.

The relative transmission power for each of the channels of the K-12 system at the output terminal and intermediate stations amount to +0.5 nepers. The transmission levels and the residual attenuation of the channels of the total frequency are standard for all modern Russian systems of high-frequency long-distance communications. If 4-wire transmission is used, the relative level is -1.5 neper at the input point of the channel and +0.5 neper at its output terminal. If 2-wire transmission is used, the residual attenuation of the channel is 0.8 neper at 800 cycles.

It is known that the parameters of underground cable lines are considerably more stable with time than the parameters of aerial lines. Nevertheless, in long distances systems, when the total attenuation of the cable pairs is quite large, the fluctuation of these attenuations caused by variation in ambient temperature may be sufficiently large. Figure 2 shows graphically how the per-km attenuation of the nonloaded cable used in the K-12 system varies when the temperature rises by 10 and 20°C. At the conventional depth used to bury the cable, i.e., 0.8 m, the temperature fluctuates as much as 20-22°C during the year. Consequently the maximum change in attenuation in a 1,000-km length may amount to 5.5 neper. To insure normal operation of the line, the above change in attenuation should be compensated for by changing the attenuation in the intermediate and terminal points with the aid of automatic level control (ARU) of the transmission. Unlike the old ARU equipment, actuated by electromagnetic mechanisms (electric motors, selectors, and relays), the K-12 apparatus employs a purely electric ARU system, operating with the aid of thermally-controlled resistors, i.e., thermistors. This has reduced the cost of the equipment and simplified the operation.

The K-12 apparatus has been developed on the basis of making its individual units identical as much as possible with the units of the V-12 12-channel system for communication over aerial lines. In addition to the individual-conversion installations, mentioned above, such common units are used for tonal calling, for differential system, for tonal (4-conductor) switching, and also for generating the individual carrier frequencies. Some of these units are of the same type as those used in the V-3 apparatus.

Block Diagram of the Terminal and Intermediate Stations

A block diagram of the terminal station of the K-12 apparatus is shown in Figure 3. In this drawing STV is the tonal-calling rack, SDS the differential system rack, SChK the 4-wire switch rack, SIP the individual converter rack, SGU the group installation rack, and VKS the entrance and switch rack.

The speech currents, passing from the subscriber's telephone set through the interurban switchboard, pass through the tonal-calling installations corresponding to each channel, and then enter the differential system DS with ballancer B; this system serves to effect the transition from the 2-wire portion of the channel to the 4-wire one. Next the currents pass through the 4-wire switching terminals, intended for measurement and channel switching and then flow to the individual frequency-converter M (modulator) which is included in the transmission path.

As a result of conversion, which is individual for each channel, the speech currents are transformed into one of the sections of the common 60-108 kc frequency spectrum. To suppress the currents of the second sideband frequencies produced during the conversion, bandpass filters PF are used, employing quartz or other piezoelectric resonators.

Next the signal currents, which occupy the 60-108 frequency spectrum flow through the differential transmission transformer (Tr-per) into the group frequency converters. The differential transformer serves to match the input impedance of bandpass filters PF, which has a nominal value of 600 ohms, with the 135 ohm input impedance of the group channel. In addition, the differential transformer permits connecting the individual spare group equipment in the transmission branch without disturbing the operation of the communication channels.

Connected between the differential transformer Tr-per and the group frequency converter GM is the rejection filter RF which serves to suppress the residual carrier frequencies that have the same value as the ARU control currents. In the group converter, which is built in the form of a ring circuit and employs copper-oxide rectifiers, the currents of the 60-108 kc frequency band are transformed with the aid of a 120-kc carrier into a linear 12-60 kc spectrum. Connected at the output of the group converter is a D-60 low-pass filter, which passes only the lower sideband frequencies from among all the frequencies entering the converter.

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After passing through the group converter, the currents enter the input of the transmission amplifier U, which raises their relative level (for each channel) to +0.5 neper. From the output of this amplifier, the linear-spectrum currents pass through line transformer LT into the line. The line transformer serves to match the input impedance of the group channel of the apparatus, which equals 135 ohms, with the wave impedance of the line, nominally 180 ohms.

In the receiving side of the terminal apparatus, the currents arrive from the line pass through the line transformer LT to the line reception amplifier U, where their relative level is raised to +0.5 neper. From the output of this amplifier the currents of the 12-60 kc line spectrum pass through lengthener [artificial line] Ud, equalizer VyR, and low-pass filter D-100; and then into the group converter of the reception frequemcy (Gr DM— demodulator). In this group converter, which is similar in construction to the transmission group converter, the currents are transformed by the 120-kc carrier into a 60-108 kc spectrum. Filter D-100 serves to block the entrance into the group converter by the noise line in the 160-228 kc spectrum, which would be converted into a 60-180 kc spectrum and would raise the noise level in the channels. The equalizer removes the amplitude-frequency distortion introduced by all the elements of the group transmission and reception channel of the terminal stations.

Connected at the output of the reception group convertor is low-pass filter D-115 which suppresses the upper sideband frequencies produced in the converter. The 60-108 kc band currents pass through the filter into the input of auxiliary amplifier VU, where their relative level is raised to -0.5 neper. They then flow through the reception transformer (Tr pr) into the channel passband filters PF and into the individual frequency converters DM (demodulators).

The currents are converted in the individual converters into a tonal spectrum, after which they are amplified in low-frequency amplifier UNCh and flow through switching terminals, differential system DS, and the tonal-call installation into the subscriber's telephone set.

The individual and group converters are supplied with carrier currents from a common generator; in the latter all the required frequencies are produced as harmonics of a fundamental 4-kc frequency. To obtain the carrier frequency for the group conversion (120 kc) a selective amplifier is used. Connected to the output point of this amplifier is a quartz filter which separates the 120-kc frequency from all the other odd harmonics of the 4-kc frequency arriving from the output of the harmonic generator.

The K-12 system employs 3 types of intermediate amplifier stations. The stations of the first type have no automatic level control equipment and are supplied with electricity, over long cable conductors, from neighboring more complicated intermediate stations or from terminal stations. The presence of permanent technical personnel is not required for the servicing of stations without ARU.

A block diagram of an intermediate station without ARU is shown in Figure 4. For each 12-channel system, such a station principally consists of 2 line amplifiers, amp A-B and amp B-A, which amplify currents in the 12-60 kc spectrum, and of 2 oppositely-directed intermediate amplifiers placed on the intermediate amplifier rack (SPU). Line transformers LT are connected at the input and output points of line amplifier. These

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transformers match the input impedances of the apparatus, approximately 135 ohms, with the wave impedance of the line, nominally 180 ohms. In individual cases amplifiers without ARU may be fed from local sources of power.

The intermediate amplifier station of the second type is a station with a "flat" ARU, in which the amplification is changed by a quantity which is the same for the entire working frequency spectrum. Stations of the second type are fed from local power supplies and depend on permanent technical service personnel. One station of this type follows 2 stations without ARU.

The block diagram of an intermediate station with flat ARU is shown in Figure 5. In its basic equipment this station differs from one without ARU only in having channel controlled receivers (PR KK) which are connected at the output point of the line amplifiers, and additional automatic regulation devices in the line amplifiers, controlled by the channel controlled amplifiers.

Finally, the intermediate amplifier stations of the third type are even more complicated, having both "flat" and "sloping" ARU and local power supply. One such station is installed following 8 stations of the preceding types. A station of the third type contains a second channel controlled receiver, connected in the same manner as the first, and has controlling devices in the line amplifiers to change the slope of the frequency characteristics of the amplification.

We shall describe below those individual units of the apparatus which are not common to the V-12 12-channel system (to be concluded).

FIGURES

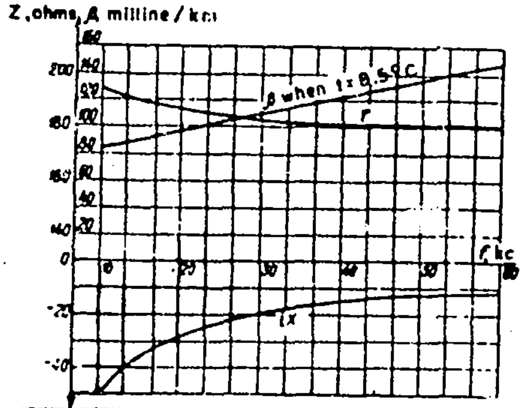

Figure 1.

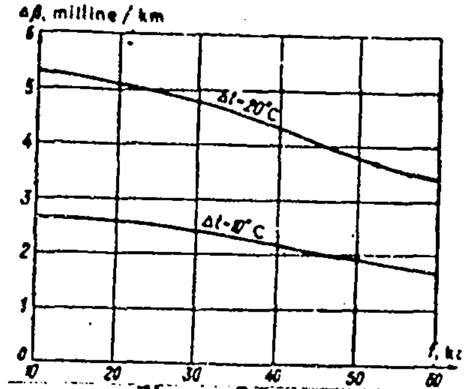

Figure 2.

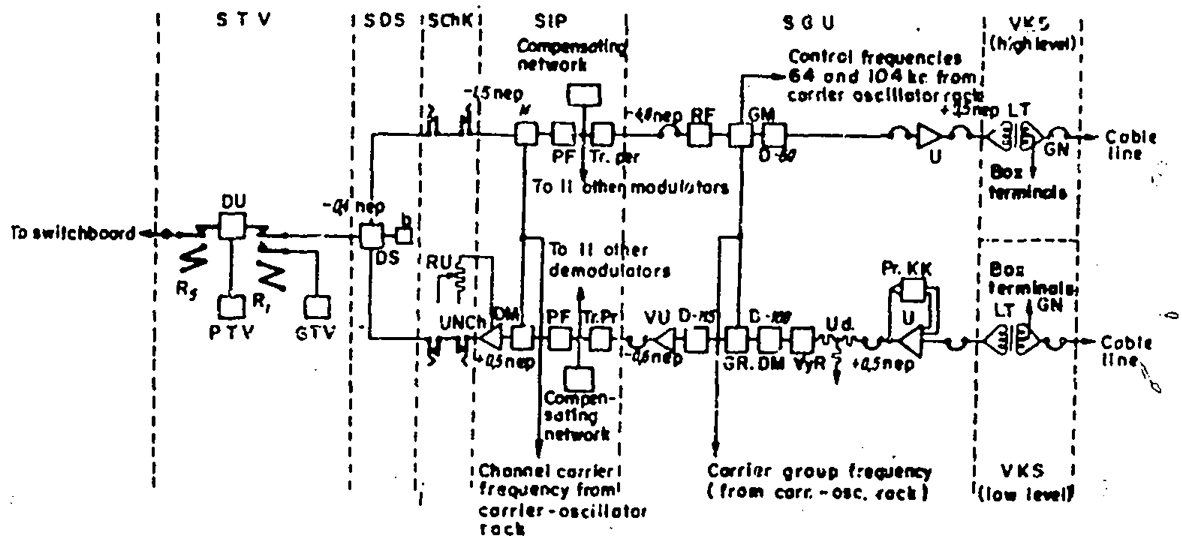

Figure 3.

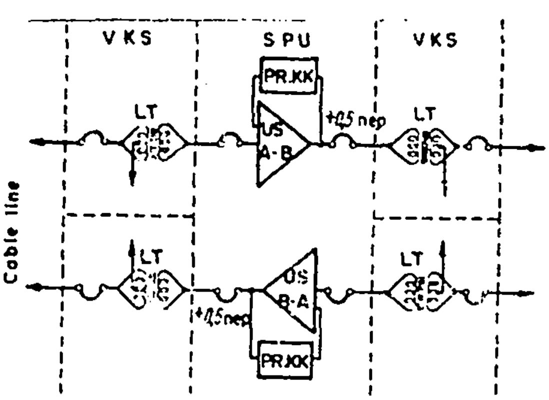

Figure 4.

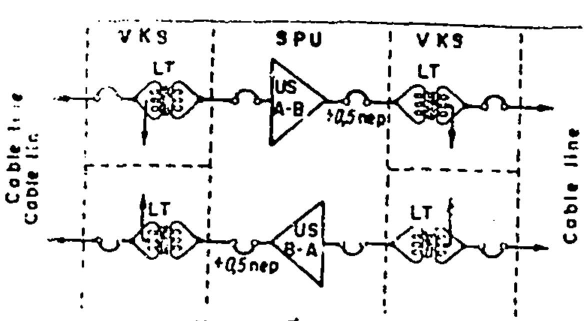

Figure 5.

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